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PRESCRIBED BURNING FOR BLACK SPRUCE REGENERATION IN NORTHWESTERN ONTARIO

by

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ABSTRACT

Prescribed fire is a viable site preparation tool for regenerating black spruce (Picea mariana (Mill) B.S.P.) in northwestern Ontario; however its use for this purpose has been limited to date. Fire is usually not necessary on lowland sphagnum-rich sites as this moss type is an excellent seedbed for black spruce germination. On sphagnum sites, burning is only recommended for removal of slash for seedbed exposure. Light burning of sphagnum sites can be used to retard the growth of sphagnum. On lowland black spruce - feather moss sites, moderate to severe burning will reduce slash and litter accumulations and consume the feather mosses thereby creating receptive seedbeds. Prescribed burning on the black spruce - alder type can produce variable results. Consideration should be given to chemically treating alder sites with 2,4-D prior to burning. This will allow for a low to medium burn under lower indices to create a favourable seedbed. On the drier upland sites, moderate to severe burning is necessary to reduce the duff layer for natural or direct seeding, although some form of microsite protection from drying and extreme temperatures may be warranted. On upland, shallow soil black spruce - feather moss sites, a moderate burn should be considered, if slash reduction is the objective. Post-fire nutrient budgeting and vegetation regrowth are discussed.

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INTRODUCTION

Black spruce (Picea mariana (Mill) B.S.P.) is the most important pulpwood species in northwestern Ontario which covers the North Central (NC) and Northwestern (NW) Regions of the Ontario Ministry of Natural Resources (O.M.N.R.). Regeneration of black spruce on sites that have been harvested is critical in providing enough high quality wood for the pulp industry in the future. Regeneration of the species is complicated and is dependent upon a variety of site factors of which site type, seedbed microsite type, and competing vegetation are of primary importance.

Many of the existing, natural black spruce stands in northwestern Ontario have originated after wildfire. The main reasons for successful black spruce regeneration after wildfire relates to the species semi-serotinous cone habit and the seedbed that is created by the fire. Prescribed burning following harvesting is one method that attempts to take advantage of one of the principal ecological processes responsible for the regeneration of black spruce.

Prescribed burning is defined as the knowledgable application of fire to a specific land area to accomplish predetermined forest management or other land management objectives (Merrill and Alexander 1987). Prescribed burning is carried out under predetermined conditions to achieve the necessary intensity of heat, fire, spread and consumption of organic matter to fulfill the reduction requirements (Anon. 1976; Isherwood and MacQuarrie 1985). By definition, prescribed burning includes the following programs: slash pile burning, railway debris burning, silvicultural burns and fuel management. The primary use of prescribed fire for black spruce regeneration in northwestern Ontario is for silvicultural purposes, specifically, site preparation for seeding and planting.

The use of fire as an effective forest management tool has been limited in the past, but recent trends indicate that its use is increasing (Gagnon 1987). Northwestern Ontario recorded 1,677 hectares (ha) burned for silvicultural purposes in the years 1985-86, and a total of 3,326 ha for the years 1986-87[1]. The use of prescribed burning as a site preparation tool had been limited in the past partly due to funding (especially associated salary funds), the long planning process and the uncertainty of the burn becoming a reality. The increase in the prescribed burning program can, in part, be related to the recent infusion of funds through the Canada-Ontario Forest Resources Development Agreement (COFRDA) and a commitment by O.M.N.R. to improve the prescribed burning program.

The specific use of fire for regenerating black spruce still plays a very minor role in managing this species. However, prescribed burning for black spruce regeneration can be effective. This paper will review the effects of prescribed fire on certain black spruce ecosystems with the intent of extracting management implications applicable to northwestern Ontario. Of particular interest to successful regeneration is matching the site type with the proper regeneration treatment and prescribed burn characteristics. Fire behaviour parameters and the resulting fire effects are beyond the scope of this paper. Readers are referred to the photo series produced by Wearn et al. (1982) for a visual presentation on fire effects of burns conducted under different conditions as represented by the Canadian Forest Fire Weather Index (FWI) System and on different site types.

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[1] O.M.N.R. Silviculture Information System, North Central and Northwestern Regions, Thunder Bay and Kenora, Ontario.

WHY BURN FOR BLACK SPRUCE REGENERATION?

When properly applied under the appropriate condition, prescribed fire can accomplish a number of objectives simultaneously including slash reduction, preparation of the seedbed and control of competition. Fire can remove logging debris and competing vegetation, consume thick organic layers on the forest floor and recycle nutrients, thereby creating a more suitable seedbed for black spruce establishment and growth. Since large areas can be treated in a short time, prescribed fire is very economical in comparison with other methods of site preparation; however, controlled burning can prove to be expensive for small areas (Viro 1974; Jeglum 1987). Resource managers must consider management objectives, site accessibility and conditions, and a host of other factors when determining silvicultural prescriptions.

The role of fire as a natural ecological component in the boreal forest region is widely recognized. Most black spruce stands originated after wildfires and are, or once were, even-aged (LeBarron 1939; Vincent 1965; Johnston 1977; Viereck 1983).

Prescribed burning can have detrimental effects when undertaken on an inappropriate site or under improper burning conditions. These detrimental effects include a loss of advanced growth and nutrient losses. In addition, fire control problems may occur if burning occurs under improper burning conditions.

BURNING OBJECTIVES FOR BLACK SPRUCE REGENERATION

The use of fire to increase seedbed quality by reducing slash and litter accumulation can be an effective means of site preparation (LeBarron 1939; Roe 1949; Heinselman 1957) and can improve planting efficiency (Endean and Johnstone 1974; Viro 1974; McRae 1985; Thomas and Wein 1985).

To meet the burn objectives, the silvicultural forester must specify the type of fire effect desired. The fire manager must then determine the indices required to meet the silvicultural objective of the burn. This is usually based upon Fuel Consumption and Depth of Burn. For the purpose of this report, the fire intensity classes outlined in Table 1 will be used. These classes were based upon those suggested by Viereck et al. 1979; Viereck and Schandelmeier 1980; and Wearn et al. 1982. As indicated in Table 1, the indices used in Ontario are presented in ranges to increase the number of burning days rather than discrete one-day only prescriptions.

The type of burn achieved is a function of fuel load, site type, weather conditions, and the ignition technique and patterns used on it. Most studies indicate that a relatively severe burn is needed to reduce slash and brush (fine and heavy fuels), and to consume most seedbeds for best regeneration effect.

Fire effect is important as it not only determines the microsite for black spruce establishment but also determines the successional sequence, and hence competitors of black spruce. For example, deeply burned sites have most of the organic duff layer (L + H horizon) removed and hence the underground roots of most shrubs have been killed (Viereck 1983). In addition, these deeply burned sites can create a favourable seedbed for black spruce's competitors (i.e. graminoids, tall shrubs). In contrast, burns having little duff reduction kill only the above ground portion of competing shrubs leaving the underground root systems to resprout.

TABLE 1: Fire Intensity Classes

1. Light Intensity Burns	
Expected Results:	Removal of fine fuels only (40 - 50%), little or no duff removal.
Weather Indices:	DMC[a] 4 - 10 BUI[b] 15 - 19 Winds up to 12 kmh
Post Burn Description:	Plants charred but original form of mosses and twigs visible, or moss and other plants brown or yellow but species usually identifiable.
2. Moderate Intensity Burns	
Expected Results:	Removal of fine fuels (50 - 70%), and some heavy fuels (10 -20%); a little duff removal (patchy)
Weather Indices:	DMC 8 - 16 BUI 18 - 28 Winds up to 20 kmh
Post Burn Description:	Organic layer partially consumed, shallow ash layer present, parts of wood twigs remaining.
3. High Intensity Burns	
Expected Results:	Removal of most fine fuels (60 - 90%) and a moderate amount of heavy fuels (20 - 35%); 1 to 4 cm of duff removal.
Weather Indices:	DMC 13 - 25 BUI 24 - 45 Winds 10 - 25 kmh
Post Burn Description:	Ash layer present, much of the organic material in the soil consumed, no discernible plant parts remaining.

[a] DMC - Duff moisture code

[b] BUI - Buildup index

Season of burn is important in influencing vegetation reduction and mortality. Light to medium intensity burns in late summer can also reduce competition as effectively as a severe spring burn.

BLACK SPRUCE SITE TYPES

Black spruce grows on both organic and mineral soils, commonly referred to as lowlands and uplands, respectively. Soil organic matter accumulation increases with high soil moisture levels (Wein 1983). Therefore burning objectives will vary according to site and will be discussed separately under the various site types.

Organic Soils

The forest floor cover on lowland black spruce sites are comprised of mosses, primarily sphagnum (Sphagnum spp.) and feather mosses (Pleurosium schreberi [Brid.] Mitt). The type of moss is dependant upon site characteristics and crown closure in the original stands. The primary black spruce lowland types and their corresponding Forest Ecosystem Classification (FEC) vegetation types in northwestern Ontario (Sims et al. 1987) that may be considered for prescribed burning are sphagnum (V37), feather moss (V33,V34), and alder (Alnus sp.)-graminoid (V35) types.

Sphagnum moss provides an excellent seedbed for black spruce germination (LeBarron 1948; Heinselman 1957; Vincent 1965; Arnott 1968, 1974; Richardson 1974; Jeglum 1981; Fleming and Groot 1984). Sphagnum-rich areas may only require slash removal to expose this natural seedbed. Aksamit and Irving (1984) concluded that prescribed fire was not necessary to regenerate the sphagnum-type

black spruce forest harvested area for either natural or direct seeding, as sufficient quality seedbeds already exist.

Prescribed burning is recommended on the sphagnum type only when sphagnum moss is poorly distributed across the site, when the site is very brushy especially to alder, or when the area is heavily covered with slash (Johnston 1977). A light intensity burn may be considered on the black spruce sphagnum-type when it is desirable to retard or reduce the growth of sphagnum. On sphagnum sites, removing black spruce slash through prescribed burning may prevent some seedling mortality due to toxicity of decaying slash on young germinants[2]. Aksamit (1982) concluded that fire intensity was not correlated to black spruce seeding success on the sphagnum sites. In some cases, more intensive fires resulted in poorer regeneration response. Growth of black spruce was found to be similar for burned and non-burned sphagnum seedbeds in a greenhouse study (Jeglum 1979).

Feather mosses are considered a poor seedbed for black spruce germination and for planting (Place 1955; Vincent 1965, 1966; Jeglum 1981). Feather moss requires shade to survive and once the overstory canopy is removed during harvesting, the mosses die and dry up. Fire can consume the feather moss, expose the peat and may expedite the proliferation of sphagnum moss. Fire is required to reduce competition and create favourable seedbeds on the feather moss sites in northern Minnesota (Aksamit 1982). Competition from shrubs and graminoids was reduced by moderate burns on the feather moss types (Aksamit 1982).

Burning feather moss sites should be conducted when the fuels are sufficiently dry to allow reasonably deep burns. Chrosciewicz (1976) found the

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[2] Wearn, V.H. Ont. Min. Nat. Res., Chapleau District, Personal communication.

degree of black spruce seedbed improvement was directly related to the depth of burn into the peat. Burns with an average depth of burn of 18 cm in hummocks and 10 cm for depression produced more favourable black spruce seedbeds than burns that averaged only 8 cm in hummocks and 5 cm in depressions. To obtain this deep burn, Chrosciewicz (1976) suggests feather moss sites be burned under a Fine Fuel Moisture Code (FFMC) of about 91, and Duff Moisture Code (DMC) of 46 and a Buildup Index (BUI) of 45. To obtain similar results in feather moss in northwestern Ontario, the ranges in indices used for moderate to high intensity burns should be used.

Burning can significantly increase both stocking and density of black spruce regeneration on feather moss sites (Chrosciewicz 1976; Haavisto and Jeglum 1978). In Manitoba, Chrosciewicz (1976) found that burning exposed 95% peat on a lowland feather moss site and moderate burning resulted in a 25% increase in stocking and a five-fold increase in number of seedlings over a light burn.

Burned feather moss seedbed may result in a reduction in both root and shoot growth of black spruce (Johnson 1971; Jeglum 1979). Deeper burning to expose the more decomposed humus layers has been recommended.

Lowland black spruce sites dominated by alder-graminoid-other tall shrubs (V35) are difficult to put back into black spruce production through burning. Prescribed burning the alder type can produce variable results as they exist on a wide range of ecological sites with respect to nutrient levels (Aksamit and Irving 1984). In some instances, alder can spread rapidly after fire (Richardson 1973). It appears that with low intensity burns that remove little or no duff, alder tends to dominate. Deeply burned alder sites can lead to an increase in shrub and graminoid competition (Aksamit 1982). On these alder sites it appears that hot prescribed burns have little benefit and that mild burns seem to favour

overall black spruce regeneration. Burns on this site type should be carried out under conditions just hot enough to consume the slash but not severe enough to stimulate the production of competing shrubs and graminoids. However, these low depth-of-burn fires may promote more vegetative suckering.

On these black spruce-alder sites, the herbicide 2,4-D can be sprayed on the area to be burned prior to ignition. This will dry the vegetation and allow for a moderate burn usually under lower indices. Although herbicide spraying prior to prescribed burning has only been used on a limited basis in northwestern Ontario (896 ha between 1984 and 1988), it has been used successfully and frequently in northern region (10,253 ha from 1984 to 1988) (Elliott 1988).

Further studies are warranted to determine the effects of burning intensities on black spruce - alder sites as they can pose a serious competition problem to black spruce regeneration.

Results and observations such as the above clearly indicate that prescribed burning on moss-rich lowland areas improves black spruce regeneration. There is however, a definite lack of growth and yield data on the influence of prescribed fires on the growth response of the crop trees.

Mineral Soils

Upland black spruce sites are highly variable in origin and in organic matter accumulation. Upland black spruce FEC vegetation types that may be considered for prescribed burning include V19 (black spruce - mixedwood - herb rich), V20 (black spruce - white birch - labrador tea/blueberry feather moss), and V32 (black spruce (jack pine) - feather moss).

Burning on these upland sites should result in a reduction in the LFH horizons to allow black spruce roots to quickly penetrate the mineral soil

(Ahlgren 1959; McRae 1985). For seeding of black spruce on upland sites, the duff layer should be removed to between 5 cm above or 10 cm below the mineral soil - humus interface (Fleming and Groot 1984) or some mineral soil should be exposed (Jarvis 1966; Johnston 1977). Charred surface organic matter is often an unfavourable seedbed for the emergence and initial establishment of seedlings due to the harsh microclimate (Arnott 1974; Jeglum 1979; Thomas and Wein 1985). However, Jarvis (1966) and Viro (1974) caution that if the humus is completely removed, drought and lethal temperatures may limit seedling reproduction. Coarse soils supporting black spruce should not be burned as the thin humus layer associated with these sites is usually completely consumed (Viro 1974). For black spruce seedling establishment after a prescribed fire, some form of microsite protection is beneficial. This may be from adjacent stands, herbaceous vegetation or use of shelter cones.

After burning on upland black spruce sites, the forest floor is a small-scale mosaic of conditions usually ranging from unburned to heavily burned (Dyrness & Norum 1983). Stocking to black spruce after fire in Manitoba was found to be highest on mineral soil seedbeds, intermediate on humus and lowest on partially decomposed duff (Jarvis 1963, 1966). Light surface fires do not favour conifer establishment as receptive seedbeds are not produced and the growth of ground vegetation is stimulated resulting in heavy competition. These findings are in agreement with Zasada et al. (1983) in Alaska who reported black spruce seedling survival only on severely burned surfaces. On fresh upland sites in Newfoundland, Richardson (1969; 1972) found burns that did not sufficiently reduce the depth of the organic mantle resulted in reduced black spruce germination; on those site types, he recommended mechanical site preparation or a more intensive burn (greater duff reduction). Similarly in Maine, Randall

(1966) found that a thin burned duff layer remained, and was not a receptive seedbed for black spruce.

In strip cuts in an upland black spruce - feather moss type in Ontario, Jeglum (1987) reported that burning resulted in low consumption of organic matter, due mainly to the low to moderate fire indices at the time. The ash surface became very dry and it was concluded that prescribed burning for site preparation should not be used on shallow-soil upland strip cuts. Perhaps burning these sites deeper would expose mineral soil which would be protected from drying and extreme temperatures by the strips. Many upland, black spruce - feather moss sites (V20, V32) can consist of shallow soil areas and deep burning should be avoided on these types of sites.

Controlled fire on certain upland seedbeds will reduce slash and competition to facilitate mechanical site preparation and planting effectiveness. Specific sites with adequate moisture regimes or protection can be burned to produce receptive mineral soil seedbeds, although further work is required to identify these areas in northwestern Ontario.

EFFECT OF FIRE ON THE BLACK SPRUCE ECOSYSTEM

Nutrients

The effects of fire on soil nutrients varies greatly with site and fire intensity (Viereck and Schandelmeier 1980). Fire restores plant nutrients into circulation by releasing nutrients from slash and the forest floor to the mineral soil by leeching of ash; this generally improves soil fertility (Armson 1977; Dyrness and Norum 1983; MacLean et al. 1983; McRae 1985b). Nutrient levels increase as a result of the flush of cations released during burning and increased microbial activity in the soil.

Fire increases the availability of phosphorus, potassium, calcium and magnesium (Ahlgren 1959; Scotter 1963; Armson 1977; Viereck and Schandelmeier 1980). For example, in Alaska Dyrness and Norum (1983) found that available phosphorus in mineral soil increased almost four-fold in moderately burned and over 16-fold in heavily burned areas.

Nitrogen is the element most subject to volatilization losses during fire and is the nutrient most limiting to growth in the boreal ecosystem (MacLean et al. 1983). It is recognized that changes in fire intensity and depth of burn will effect the amount and form of nitrogen (Armson 1977). Zasada et al. (1987) have recently suggested a relationship between burning severity and growth on black spruce/feather moss sites. The best growth and survival were found on severely burned microsites, with the differences in growth being attributed to both chemical and physical soil factors. According to Viro (1974), nitrogen losses may be significant through volatilization, but an increase in mineralized nitrogen (available) usually results. He concludes that prescribed burning does not lead to serious impoverishment of the soil, especially when burns are not frequent. Dyrness and Norum (1983) showed significant increases in total nitrogen in moderately burned areas and a slight decrease in heavily burned areas. There is a need to further study nutrients losses as they relate to fire intensity and depth of burn.

The removal of organic matter also results in warmer soil temperatures and reduced soil acidity (increased pH), both of which may favourably affect nutrient availability (Scotter 1963; Viereck et al. 1979; Zasada et al. 1987). The increase in soil temperature is due to the removal of the insulating organic layer, change in surface albedo and removal of the vegetation overstory.

Competition Responses

Prescribed burning can be used as a vegetation management tool. Positive vegetative response by fire on the initial performance of black spruce and the subsequent need for release treatment is possible.

On lowland sites, Aksamit (1982) has documented changes in competing vegetation on sphagnum, feather moss and alder sites in northern Minnesota. On the sphagnum sites dominated by sphagnum and Labrador tea prior to burning, burning reduces the sphagnum and stimulates graminoids and other tall shrubs. This initial post fire increase in graminoids diminishes with time. The deeper the depth of burn and the lower the fuel moisture, the more graminoids are present after the burn. A light intensity burn with no duff removal in sphagnum sites will temporarily retard sphagnum growth.

On feather moss sites, burning increases both graminoids and other tall shrubs. The feather moss seedbeds are replaced with more favourable seedbed species of sphagnum and polytrichum.

On alder sites, burning reduces the coverage of alder but results in an increase of graminoids and other tall shrubs, especially after a severe burn. This reduction in alder is only temporary and with time it increases to compound the shrub competition on these sites. To avoid this, alder sites should be chemically treated with herbicide prior to prescribed burning.

On upland sites, there appears to be less competing vegetation after burning when compared to mechanical site preparation[3]. In addition, there is

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[3] Prescribed burn study, North Central Region, Preliminary results, October 1988. On file with the Northwestern Ontario Forest Technology Development Unit.

less balsam fir and other ingrowth on areas subjected to prescribed burning than those mechanically site prepared.

The initial high rate of growth of post-fire vegetation helps to minimize nutrient loss by retaining available nutrients in plant biomass which may be lost to leaching or erosion (Armson 1977; MacLean et al. 1983). The rapid and often luxuriant herbaceous growth also provides a cool moist microclimate and conditions of shade necessary for black spruce establishment on some sites (Ahlgren 1959). A deep burn will kill the roots of most shrubs while a light burn will encourage the proliferation of shrubs from underground rhizomes and root and stump sprouts (Viereck 1983). Once again, the timing of the burn (i.e. season of the year) will influence the type of burn and the subsequent amount of competition reduction.

Growth Responses

Prescribed burning can result in early black spruce seedling establishment, better survival and accelerated seedling growth (Chrosciewciz 1976; Zasada et al. 1983). Unfortunately, detailed information on the influence of prescribed burning on post-burn black spruce growth is limited.

On lowland feather moss sites, Chrosciewicz (1976) found that improvement of seedbeds by moderate burning was beneficial to the growth of the seedlings. After five growing seasons, the height of dominant black spruce seedlings averaged 28 cm on moderately burned plots compared to 20 cm for both the lightly burned and the unburned control.

Recent data from upland black spruce/jack pine stands in Geraldton district[4], suggest that trees established following prescribed fire have faster mean height growth and higher cumulative volumes when compared to unburned control plots. On lowland sites in Kapuskasing District, McRae (1985a) suggests that there are no major differences in growth parameters (stump diameter, total height, crown width) between prescribed burning and mechanical site preparation (barrels and chains, young's teeth).

Further documentation of black spruce growth responses from prescribed burning treatments compared to unburned controls or other forms of site preparation are required in promoting the use of prescribed burning as a regeneration treatment.

SUMMARY AND RECOMMENDATIONS

Prescribed fire is a viable site preparation tool for regenerating black spruce in northwestern Ontario. The objective for burning, crop tree growth response, and competition response varies with site type.

I. Organic Soils

a) Sphagnum: Prescribed burning is not usually required to regenerate the sphagnum type for natural or direct seeding, as sphagnum moss is an excellent black spruce seedbed. Burning sphagnum sites can stimulate graminoid competition although this competition is temporary. Prescribed burning is only recommended on sphagnum sites when slash reduction is required.

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[4] Ibid.

b) Feather moss: Moderate to severe burning on feather moss sites can improve black spruce regeneration. Fire consumes the feather moss, exposes the peat, encourages the proliferation of more favourable seedbeds such as sphagnum and reduces the competition from graminoids and other tall shrubs.

c) Alder: Prescribed burning on the black spruce - alder type can produce variable results, as they exist on a wide range of ecological sites with respect to nutrients. In general, mild burns on the alder type appear to favour black spruce regeneration response. Severe burning reduces the coverage of alder but increases graminoids and other tall shrubs which are competitors of black spruce. Consideration should be given to chemically treating alder sites with 2,4-D prior to burning. This will allow for a low to medium burn under lower indices and create a favourable seedbed.

2. Mineral Soils

Prescribed burning on upland black spruce sites should result in a reduction in the LFH horizon to just above the mineral soil - humus layer. If the humus layer is completely removed, drought and lethal temperatures may limit seedling reproduction. Some form of microsite protection (block or strip cuts, herbaceous vegetation, shelter cones) is warranted for seedling establishment.

3. Nutrients

Burning increases soil fertility by releasing nutrients tied up in slash and organic matter. Temporary increases in soil pH and soil temperatures favourably affect nutrient availability. Even though there are nitrogen losses through volatilization, available forms of nitrogen are normally higher after prescribed burns.

4. Growth Response

Prescribed burning can result in earlier black spruce seedling establishment, better survival and accelerated seedling growth when compared to unburned control; however, the data is limited. Further trials and data are needed on post-burn regeneration growth.

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